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THE PURPOSE OF THIS SURVEY WAS TO DETERMINE EXPOSURE LEVELS TO N-NITROSODIMETHYLAMINE (NDMA), HYDRAZINE, AND 1, 1-DIMETHYLHYDRAZINE (UDMH) DURING VARIOUS JOB OPERATIONS AND WIND CONDITIONS AT THE ROCKY MOUNTAIN ARSENAL (RMA) HYDRAZINE FACILITY.

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UNITED STATES ARMY ENVIRONMENTAL HYGIENE AGENCY

ABERDEEN PROVING GROUND, MD 21010

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INDUSTRIAL HYGIENE SPECIAL STUDY NO. 55-66-0216-81
N-NITROSODIMETHYLAMINE, HYDRAZINE, AND 1, 1-DIMETHYLHYDRAZINE
EXPOSURES AT THE HYDRAZINE BLENDING FACILITY
ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, CO

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DEPARTMENT OF THE ARMY
US ARMY ENVIRONMENTAL HYGIENE AGENCY
REGIONAL DIVISION - WEST
FITZSIMONS ARMY MEDICAL CENTER
AURORA, COLORADO 80045

Mr. Desan/lh/943-8881

28 OCT 1 0

HSE-MW

SUBJECT: Industrial Hygiene Special Study No. 55-66-0216-81, N-Nitrosodimethylamine, Hydrazine, and 1, 1-Dimethylhydrazine Exposures at the Hydrazine Blending Facility, Rocky Mountain Arsenal, Commerce City, CO, 16-27 June 1980

Commander
USA Materiel Development and
Readiness Command
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1. Due to fluctuating wind conditions and apparent multisources of exposure, N-Nitrosodimethylamine (NDMA) is prevalent throughout the facility. Since there is no Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for NDMA, no safe distance can be established within the Hydrazine Blending Facility where respiratory protection is not required. Therefore, respiratory protection should be required for all entries into the Facility when in operation, up to 24 hours after operation, and for all maintenance work on the systems. Since no air purifying respirator has been tested for NDMA, only air supplied or self-contained breathing air respirators are considered adequate.

2. Recommendations are also made for reducing the number of sources of exposures.

ROBERT G. GRODT, P.E.
LTC, MSC
Chief, Regional Division-West

CF:
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Cdr, AMRCOM (DRSAR-SG)
Cdr, HSC (HSPA-P)
Cdr, FAMC (PVNTMED Actv) (2 cy)
Cdr, RMA (2 cy)
Supt, AHS (HSA-IPM)
Cdr, USAEHA (HSE-M) (2 cy)

Ind Hyg Special Study No. 55-66-0216-81, N-Nitrosodimethylumine, Hydrazine, and 1, 1- Dimethylhydrazine Exposures at the Hydrazine Blending Facility, RMA, Commerce City, CO, 16-27 Jun 80

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DEPARTMENT OF THE ARMY
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28 OCT 1980

HSE-MW

INDUSTRIAL HYGIENE SPECIAL STUDY NO. 55-66-0216-81
N-NITROSODIMETHYLAMINE, HYDRAZINE, AND 1, 1-DIMETHYLHYDRAZINE EXPOSURES AT THE HYDRAZINE BLENDING FACILITY ROCKY MOUNTAIN ARSENAL COMMERCE CITY, CO 16-27 JUNE 1980

1. AUTHORITY.

a. AR 40-5, Health and Environment, 25 September 1974.

b. Letter, HSE-ZX, Rocky Mountain Arsenal, 29 April 1980, subject: Request for Technical Assistance, with indorsements.

2. REFERENCES. See Appendix A for a list of references.

3. ABBREVIATIONS. See Appendix B for a list of abbreviations.

4. PURPOSE. To determine exposure levels to N-Nitrosodimethylamine (NDMA), Hydrazine, and 1, 1-Dimethylhydrazine (UDMH) during various job operations and wind conditions at the Rocky Mountain Arsenal (RMA) Hydrazine Facility.

5. BACKGROUND.

a. UDMH upon exposure to air may be converted to trace amounts of the potentially carcinogenic compound N-Nitrosodimethylamine (NDMA). UDMH may also contain small amounts of NDMA as a contaminant (see references 13 & 14). References 2, 4, and 5 found NDMA at various locations during transfer/blending operations at the RMA facility. Current law* prohibits any occupational exposure to NDMA. To support previous recommendations made for the use of positive pressure, air supplied or self-contained breathing air (SCBA) respirators during all entries into the facility would be logistically and administratively difficult. RMA, therefore, requested a more detailed study be performed (reference 1) to equate job operations and wind directions to exposure levels in order to determine if a minimum safe distance can be established, and to pinpoint the main sources of exposures.

*See paragraph 6E(2)(b) on page 3.

Use of trademarked names does not imply endorsement by the US Army, but is intended only to assist in identification of a specific product.

b. References 6 and 7 discuss the potential for artificial formation of Nitrosoamines both in Tenax® sorbent and during analytical procedures when artifacts of the compound are present, thus potentially indicating a false high exposure. Also discussed is the low break through volume for NDMA on Tenax® sorbent, thus potentially indicating a false low exposure. Since previous Air Force and Army studies (references 2,4,& 5) used Tenax® sorbent, the scope of this study was expanded to include comparative sampling using Tenax® and Thermosorb/N® sorbents. Thermosorb/N® is a sorbent which inhibits the artificial formation of Nitrosoamine compounds and has good retention for NDMA.

c. In addition to the undersigned, CPT Steven J. Stone, CPT Kenneth E. Hergenrader, Mr. Michael J. Richen, of this Agency and Mr. George Podalak, USAEHA contributed in conducting this study. The Army Atmospheric Science Laboratory RMA provided all wind data. Personnel contacted during this study are listed in Appendix C.

6. FINDING AND DISCUSSION.

a. The Hydrazine Facility. The hydrazine facility is a transfer/storage facility for hydrazine and UDMH and a blending/storage facility for Aerozine 50. Hydrazine is loaded or down loaded from railroad tank cars, tank trucks, 55 gallon drums, and storage tanks. Four separate loading stations are involved and a diagram of the facility can be found on page D-2.

b. Sampling Strategy. To determine exposure levels six fixed sampling points within the facility and two control points outside the facility were chosen. To characterize exposures at the various transfer/blending operations, upwind, and downwind samples were also taken. Sampling points are listed in Appendix D.

Method of Collection. Samples were collected on sorbent materials using [illegible] and MSA model G sampling pumps. The adsorption media for hydrazines was 400 mg of 40/60 mesh silica gel coated with concentrated sulfuric acid. For NDMA, comparative samples were taken using 150 mg of Tenax® sorbent (the type of tube used during the previous Army study, reference 2) and commercially prepared Thermosorb/N® cartridges. Sampling rates and times were adjusted (as far as practical) to obtain optimum sample volumes of 60L for NDMA and 60L for the hydrazines. Pump calibrations were verified daily.

Method of Analysis. Hydrazine samples were analyzed by NIOSH [illegible] Chemical Analytical Method 248 (see reference 11). The analytical method for NDMA consisted of desorption of samples with 2 ml [illegible] measurement by gas chromatograph equipped with a dual nitrogen-phosphorus detector. The peak identified as NDMA during the analysis of Tenax® and Thermosorb/N® cartridges had a retention time 6.7 min. on a 6' SP-1000 column and was confirmed by Gas Chromatography Mass Spectrometry (GC-MS) analysis using the same column.

e. Standards.

(1) Hydrazines

(a) ACGIH-TLV 1979ed, Hydrazine 0.1 ppm, UDMH 0.5 ppm

(b) NIOSH Recommended Standard, Hydrazine 0.03 ppm, UDMH 0.06 ppm

(c) OSHA Standard 29 CFR 1910.1000, Hydrazine 1 ppm, UDMH 0.5 ppm

(2) NDMA

(a) ACGIH-TLV (reference 16) "Because of extremely high toxicity and presumed carcinogenic potential of N-Nitrosodimethylamine, contact should not be permitted by any route."

(b) OSHA Standard 29 CFR 1910.1016, currently there is no established Permissible Exposure Limit (PEL); however reference 14 indicates there is some feeling that a PEL may be established in the order of 1 ppb. To confirm this, Mr. Tipton, OSHA Standards Division, Washington, DC, point of contact listed in reference 15, was contacted. His office has no information concerning the establishment of a PEL. Dr. David West, NIOSH Criteria Document Section, Rockville, MD, was also contacted. A NIOSH Intelligence Bulletin on N-Nitrosodimethylamines will be published in the near future but will not address the establishment of a PEL. Although this standard applies only to mixtures containing more than 1% NDMA and military specification MIL P 25604 limits NDMA contamination in UDMH to 0.01%, UDMH can spontaneously oxidize into NDMA on exposure to air. Therefore, NDMA exposures from NDMA contamination in UDMH accounts for only a portion of the workers overall exposure to NDMA and the less than 1% exclusion is inappropriate.

f. Comparative Sampling Tenax® vs Thermosorb/N® Sorbents. One hundred and forty one pair of comparative samples were taken. Of these, forty pair of results were found to be, and were reported as, less than 0.17 ppb. Of the remaining 101 pair, 96 Tenax® values were below the corresponding Thermosorb/N® values. Tenax® values ranged from 2-275% (average 34%) of the Thermosorb/N® value. Due to the large fluctuation between sample pairs a laboratory efficiency study was conducted. A 150 mg Tenax® tube was fortified with 100 ng NDMA and connected in series to an identical unfortified tube. Laboratory air was pumped through both tubes at 1 Lpm for 100 minutes. The two tubes were desorbed and analyzed as previously described. The fortified tube (front tube) contained 38 ng and the unfortified tube (backup tube) contained 55 ng. Ninety three percent of the 100 ng was recovered from the combination of both tubes of which only 41% of the recovered amount was retained on the fortified front tube. The same procedure was used with two Thermosorb/N® cartridges. A recovery of 96% was obtained from the analysis of the fortified cartridge (front cartridge). The unfortified cartridge yielded an undetectable concentration. A synthetic sample of NDMA was then generated in the laboratory and a commercial 150 mg Tenax® tube was used to collect 100

L of sample. Of the theoretical 200 ng, only 28% was recovered. These results confirm reference 6's finding that Tenax® has a poor retention for NDMA and that, under conditions present at RMA, NDMA breakthrough indicating a false low exposure was far more dominant than artificial formation of the compound. Therefore, values reported in Appendix E are those obtained from collection on Thermosorb/N® cartridges unless otherwise stated. A tabulated list of Tenax® vs Thermosorb/N® values are listed in Appendix F. A comparison of the Air Force collection technique, which uses Tenax® tubes containing 2.5 - 3 grams of sorbent, was not made.

g. Ambient Levels. Ambient air samples were collected on 17 June to determine background levels at the hydrazine facility when not in operation. Hydrazines were not detected. However, NDMA was detected in the mixer area, drum storage area, and tank storage area indicating that leaks must exist in the system. Although hydrazines were not detected in the sub-ppm range (the level at which hydrazine standards are established), does not mean that they are not present in the sub-ppb range (the level at which NDMA was detected).

h. Specific Operations.

(1) Drum Filling. On 18 June, 55 gallon drums were filled with hydrazine and UDMH. The operation required two workers; one to position the drums with the forklift, the other to make connections and do the filling. The forklift operator wore an M9 Gas Mask, while the filler wore a SCBA respirator. The forklift was not approved for use in explosive atmospheres. Sample results (page E-3) show hydrazines being detected around the filling operation but show no increase in levels throughout the rest of the facility. UDMH results, however, were not only high around the operation, but were significantly higher than ambient conditions in the sump area, mixer area, and the drum storage area even during the afternoon hydrazine filling operation. This is believed to be due to the residual UDMH from earlier operations.

(2) Drum Rinsing/Steam Cleaning. Seven drums were also cleaned on 18 Jun. The operation consisted of one employee (in a SCBA respirator) opening the drums and partially filling them with water. Three other employees (without respiratory protection) then rolled the drums on their sides to insure complete rinsing and drained them onto the concrete slab. The contaminated water was drained through a floor drain to the holding sump. A spot check of the seven drums (using a Drager indicator tube) indicated that none contained a significant hydrazine or UDMH residue prior to the initial rinsing. After rinsing, the drums were rolled to the NW corner of the slab and steamed. Workers did not wear respiratory protection during steaming. Sample results (page E-3) show hydrazines pose no direct problem although levels were high enough to require respiratory protection during both rinsing and steaming.

(3) Railroad Car to/from Storage Tanks. These operations required two employees to make and break connections and one employee to monitor transfer gauges (all three wore SCBA respirators). Hydrazine was

transferred on 19 June and Aerozine 50 on 20 and 23 June (see pages E-4, E-5, & E-6). In general, hydrazines pose no problem but NDMA levels were found to be higher than ambient conditions throughout the facility, with levels being greater during Aerozine 50 transfer as would be expected.

(4) Transfer, Tank Truck to/from Storage Tanks. This operation also requires two workers to make and break connections and one to monitor the flow gauges. UDMH was transferred on 20 and 24 June (see pages E-5 & E-7). NDMA levels were found to be higher than during railroad car transfer operations. This could either be due to pure UDMH being transfered (as compared to Aerozine 50 during the railroad car transfer operation), or due to minor leaks in the truck transfer system.

(5) Changing of the UDMH filter on the morning of the 25 June would partially, but not totally, account for the high NDMA levels found that morning (see page E-8 and filter cleaning operation 24 June, page E-7). Residual contaminated water in the drains, on the concrete slabs, and in the sump, in addition to suspected minor leaks in the system, are believed to account for the rest. This would tend to indicate that NDMA levels higher than ambient are present a day following transfer operations.

(6) On 26 June, UDMH was transferred from a truck to a railroad car. However, due to contamination in the UDMH, the railroad car was vented directly to atmosphere in an attempt to install a shorter siphoning port. This was a non-routine operation. High NDMA levels were found throughout the hydrazine facility even at the 7th street perimeter fence.

i. Potential Sources of Exposures (Other than leaks in the System and making/breaking of connections).

(1) The main source of exposure in the mixer area is believed to be the system vent-scrubber. Contaminated air from the system is passed through a water scrubber before being vented to atmosphere. The scrubber water is discharged through a floor drain to a holding sump. Exposures may occur from poor scrubber efficiency and from the air gap between the scrubber and floor drain.

(2) Even though the sump is now being precharged with calcium hypochlorite to oxidize the hydrazines, and a floating plastic cover has been added to reduce exposed surface area, the sump still appears to be a main source of exposure. The capacity of the pump which circulates the sump water appears to be inadequate to insure rapid complete mixing.

(3) Although the bulk of the contaminated water from drum rinsing is removed through a floor drain, the remaining standing water can be a significant source of exposure when a contaminated drum has been rinsed.

(4) Tank levels must be checked manually with a dip stick, which releases the hydrazines directly to air.

(5) All floor drains leading to the sump are a potential source of exposure if not equipped with a water trap or if the water level in the trap is not maintained.

j. Medical Surveillance. Hydrazine Facility workers are included in the RMA Medical Surveillance Program and are receiving proper examinations.

7. CONCLUSION. NDMA levels are prevalent throughout the hydrazine facility. Due to fluctuating wind conditions, apparent multisources of exposure, and lack of an established safe exposure limit to NDMA, no safe distance can be established within the facility where respiratory protection is not required. Since no air purifing respirator has been tested for its efficiency and breakthrough times for NDMA, only air supplied or self contained breathing air respirators are considered adequate (see references 14 & 15).

8. RECOMMENDATIONS.

a. The following recommendations are made for reducing the number of sources of exposures at the hydrazine facility until recommendations contained in the study by Sterns and Rogers, for a total upgrade of the facility can be made:

(1) Throughly inspect all pipes, valves, gauges, and fittings repairing any leaks found.

(2) Prechlorinate the scrubber water to improve its efficiency by reducing the concentrations of hydrazines and NDMA at the source. This would eliminate the need for a larger pump for circulating the water in the sump. Prechlorinated water could also be used for rinsing the concrete slab after drum rinsing operations. It will be important to maintain a residual chlorine concentration to ensure complete oxidation.

(3) Insure that all floor drains leading to the sump have water traps and that water levels in the traps are maintained.

(4) Provide a separate closed drain for the scrubber, it could be attached to existing plumbing on the downstream side of the floor drain water trap.

(5) Provide fluid level gauges on the storage tanks to eliminate the need for checking tank levels with dip sticks.

b. In the interim, until the facility can be upgraded, require the use of air supplied or self contained respiratory equipment for all entries into the facility when in operation, for all entries within 24 hours after an operation, and for all personnel performing maintenance on the system (see references 14 & 15).

Ind Hyg Special Study No. 55-66-0216-81, N-Nitrosodimethylamine, Hydrazine, and 1, 1- Dimethylhydrazine Exposures at the Hydrazine Blending Facility, RMA, Commerce City, CO, 16-27 Jun 80

c. Should non-routine operations be performed where the hydrazines are vented directly to air (for example cleaning storage tanks) restrict entry into the area 100 yards beyond the current perimeter.

d. The Safety Office should make determinations as to whether the fork lift currently being used is adequate for use in an area where flammable and combustible liquids are being transferred, and as to whether the smocks currently being used afford adequate splash/spill protection.

9. TECHNICAL ASSISTANCE. Assistance may be obtained by calling USA Environmental Hygiene Agency, Regional Division-West, AUTOVON, 943-8881 or by writing through channels to Commander, USA Health Services Command, ATTN: HSPA-P, Fort Sam Houston, Texas 78234, in accordance with paragraph 1-5, AR 40-5.

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APPENDIX A

References

1. LTR: HSE-ZX, Rocky Mountain Arsenal, 29 April 1980, Subject: Request for Technical Assistance, with indorsements.

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5. LTR: SFOT, Headquarters, San Antonio Air Logistics Center (AFLC), Kelly Air Force Base, TX, 13 October 1976, Subject: NDMA Analysis at RMA.

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10. US Department of Health, Education, and Welfare Publication No (NIOSH) 78-172, Criteria for a Recommended Standard...Occupational Exposure to Hydrazines.

11. US Department of Health Education and Welfare Publication No (NIOSH) 77-157A, Hydrazine Compounds in Air, P & CAM 248.

12. Proceeding of the Conference on Environmental Chemistry of Hydrazine Fuels. CEEDO-TR-78-14, Tyndall AFB, September 1978.

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APPENDIX B

Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienist
L	Liters
MSA	Mine Safety Appliance Company
mg	milligrams
mg/m^3	milligrams per cubic meter
mph	miles per hour
ND	not detected
NDMA	N-Nitrosodimethylamine
ng	nanogram
NIOSH	National Institute for Occupational Safety and Health
NO2	Nitrogen Dioxide
OSHA	Occupational Safety and Heal h Act or Administration
ppb	parts per billion
ppm	parts per million
SCBA	Self Contained Breathing Air Respirator
SLpm	Standard liters per minute
RMA	Rocky Mountain Arsenal
TLV	Threshold Limit Value established by ACGIH
UDMH	Unsymmetrical Dimethylhydrazine or 1, 1-Dimethylhydrazine
USAEHA	US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD

APPENDIX C

Personnel Contacted

COL Williams, Cdr RMA
Dr. Throm, Occupational Health Physician/ RMA Health Clinic
Mr. Ursillo, Chief/Plant Operations
Mr. Crabtree, Plant Engineer
Mr. Kim, Safety Engineer/RMA
Mr. Lynch, Foreman/Hydrazine Facility
Mr. Hartberger, Industrial Hygiene Technician, Fitzsimons

APPENDIX D

Sampling Points

1 7th Street Fence. Samplers were located 50' west of north gate, 6' above the ground (see Fig D-1).

2 West Perimeter Fence. Samplers were located on the south side of the west railroad track gate 6' above the ground (see Fig D-1).

3 Sump Area. Samplers were located at the north-east corner of the sump, 3'6" above the ground (see Fig D-1).

4 Mixer Area. Samplers were located 2' 6" east of the center of the mixer, 4'6" above the ground (see Fig D-1)

5 Drum Storage Area. Samplers were located 7' east of Building 759, 3'6" above the ground (see Fig D-1).

6 Tank Storage Area. Samplers were located between storage tanks HAS 2 and HAS 3, 3'4" above the ground

7 Rocky Mountain Arsenal Fire Station.* Sampler was located on the telephone pole at the south-east corner of the fire station, 6' above the ground.

8 Fitzsimons.* Sampler was located outside the second floor window of Building 603 at Fitzsimons Army Medical Center.

A Samplers were attached to a tripod 5' above the ground and located upwind of the operation (see Fig D2-D13).**

B Samplers were attached to a tripod 5' above the ground and located downwind of the operational (see Fig D2-D13).**

C Sampler were attached to a tripod 5' above the ground or work platform and located as close to the operation as practical (see Fig D2-D13).**

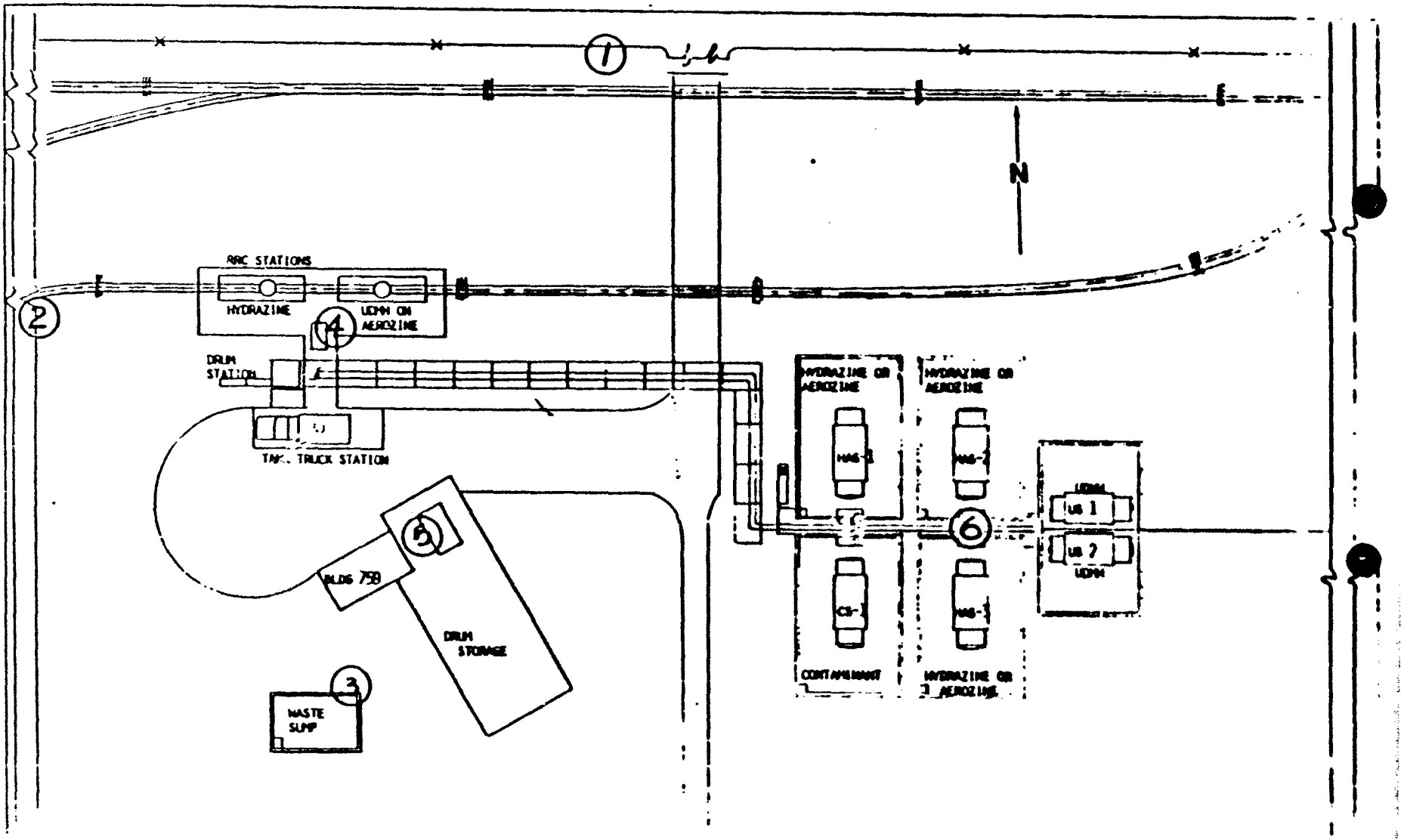
*Samples collected at sampling points 7 & 8 represent control samples for NDMA.

**Samplers were located upwind and downwind as determined by the dominant wind condition at the start of the sampling period and samplers remained at these positions through the sampling period. However due to fluctuating wind conditions, sampler locations, although placed upwind and downwind at the start of the sampling period, may or may not represent the dominant upwind or downwind positions for the sampling period. See Figures D2-D13 for sampler locations and average wind conditions during specific sampling periods.

APPENDIX D

SAMPLING POINTS 1-6
17-26 JUNE 80

FIGURE D-1



APPENDIX D

FIGURE D-2: 18 June 1980, Sampler locations during the filling of drums with UDMH (0944-1148 hours).

(A) 11' NW of the drum.
(B) 23' SE of the drum.
(C) Inside the shelter, W of the scale.

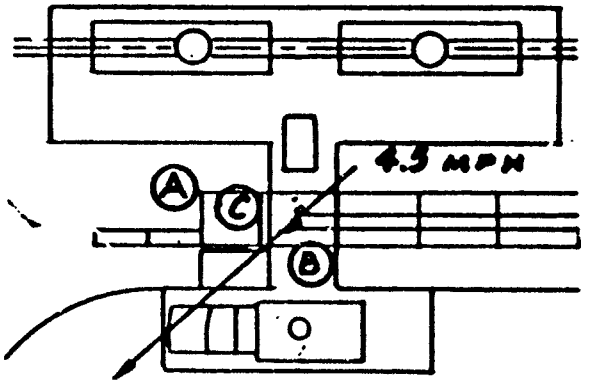
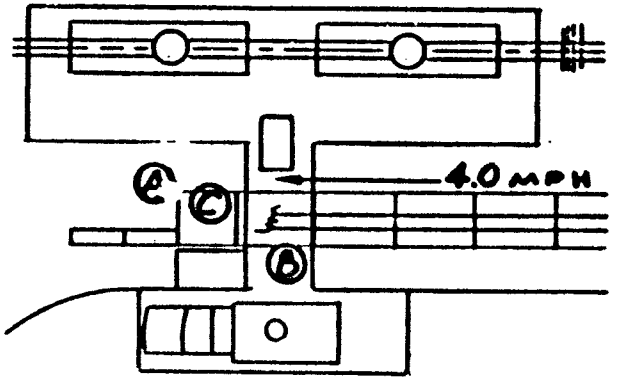


FIGURE D-3: 18 June 1980, Sampler locations during the filling of drums with Hydrazine (1352-1420 hours).

(A) 11' NW of the drum.
(B) 23' SE of the drum.
(C) Inside the shelter, W of the scale.



APPENDIX D

FIGURE D-4: 18 June 1980, Sampler locations during drum rinsing operation (1250-1320 hours).

(A) 18' S of drums.
(B) 15' N of drums.
(C) Next to drums.

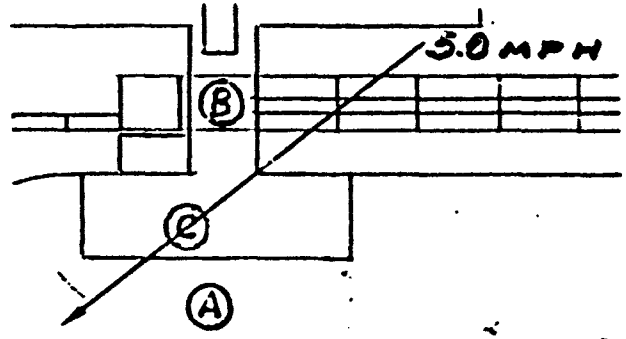
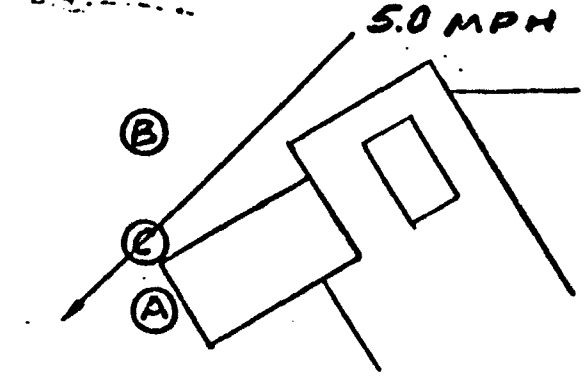


FIGURE D-5: 18 June 1980, Sampler locations during the steam cleaning of drums (1320-1335 hours).

(A) 8' S of drum.
(B) 15' N of drum.
(C) Next to drums.



APPENDIX D

FIGURE D-6: 19 June 1980, Sampler locations during all sampling periods.

(A) 36' N of the railroad car connection port.
(B) 36' S of the railroad car connection port.
(C) On platform leading to the railroad car connection port.

Figure D-6a Sampling periods: 0830-0845+0908-1000
1000-1107 hours
1107-1212 hours

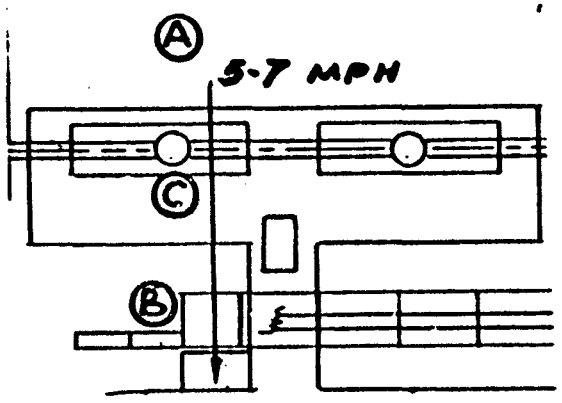


Figure D-6b Sampling periods 1212-1306 hours

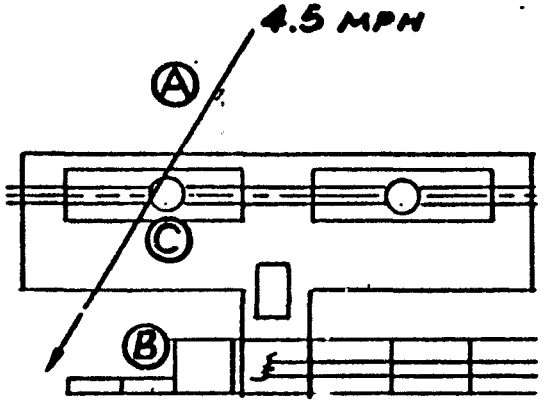


Figure D-6c Sampling periods 1306-1400 hours

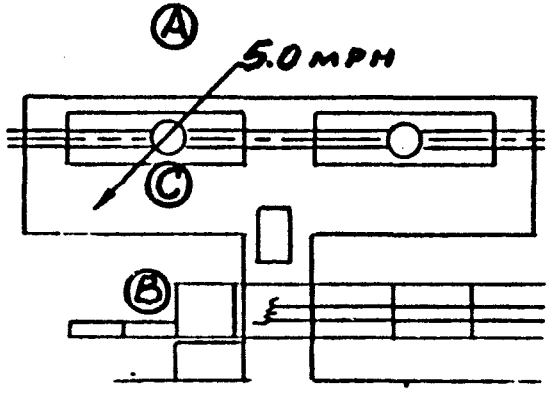


FIGURE D-7: 20 June 1980, Sampler locations during UDMH transfer from storage tank to truck.

(A) 36' S of truck connection port.
(B) 45' N of truck connection port.
(C) On platform leading to truck connection port.

Figure D-7a Sampling period: 0830-0935 hours

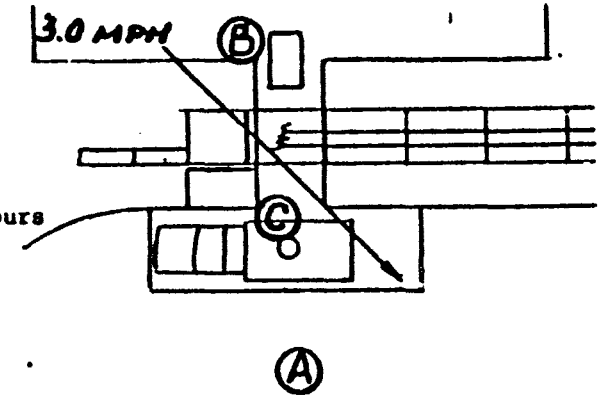


Figure D-7b Sampling period: 0935-1040 hours

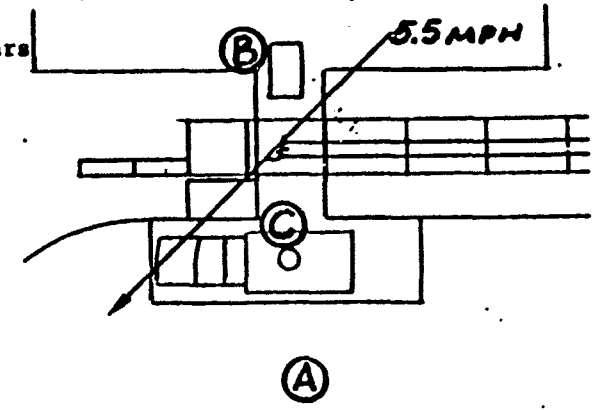
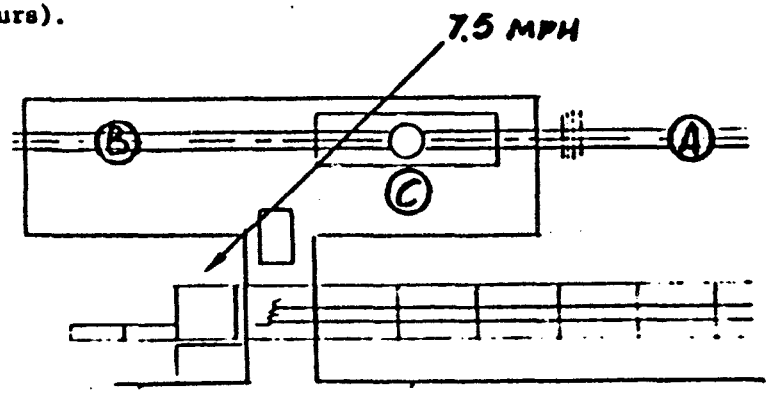


FIGURE D-8: 20 June 1980, Sampler location during transfer of Aerozine 50 from storage tank to railroad car (1040-1203 hours).

(A) 45' E of railroad car connection port.
(B) 45' W of railroad car connection port.
(C) On platform leading to railroad car connection port.



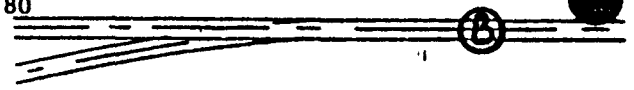


FIGURE D-9: 23 June 1980, Sampler locations during transfer of Aerozine 50 from railroad car to storage tank (1013-1108 hours).

(A) S of railroad car (at yellow line).
(B) N of railroad car (between tracks).
(C) On platform leading to the railroad car connection port.

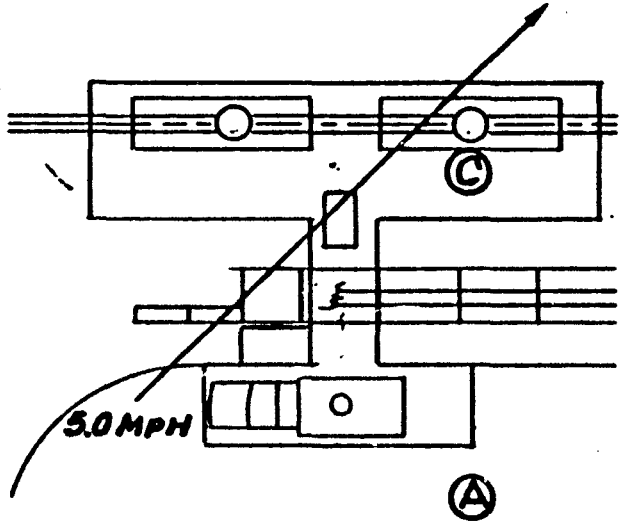
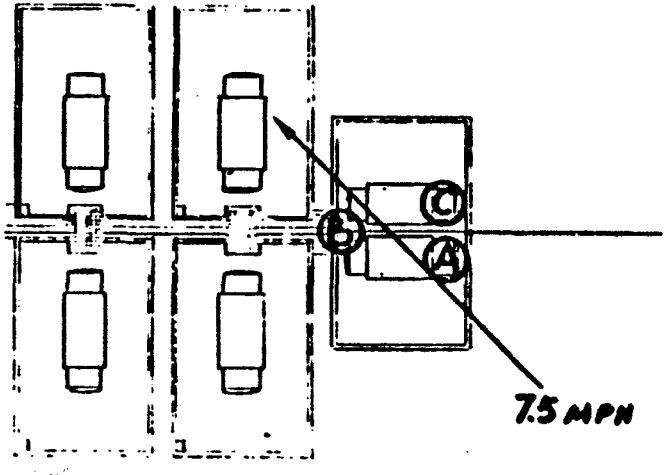


FIGURE D-10: 23 June 1980, Sampler locations during sampling of storage tanks US1 and US2.

(A) Westside of the sampling port platform on tank US2.
(B) On platform on the west end of storage tanks US1 and US2.
(C) Westside of the sampling port platform on tank US1.



APPENDIX D

FIGURE D-11: 23 June 1980, Sampler locations while connecting truck (1452-1517 hours).

(A) 40' E of the truck connection port.
(B) 50' W of the truck connection port.
(C) On platform leading to the truck connection port.

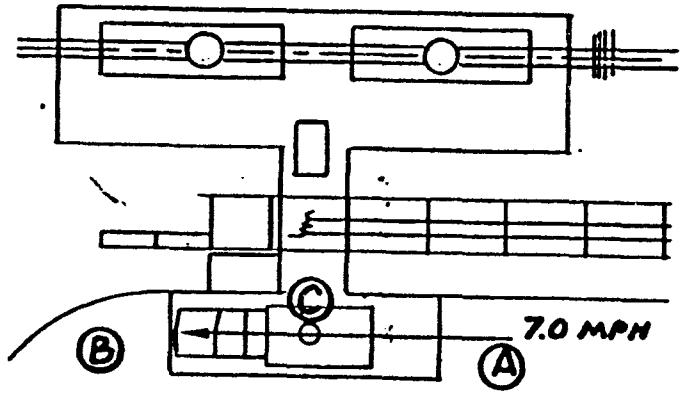


FIGURE D-12: 24 June 1980, Sampler locations during all sampling periods.

(A) 35' E of truck connection port.
(B) 35' W of truck connection port.
(C) On the platform leading to the truck connection port.

Sampling periods: 0936-1036 hours
1036-1136 hours
1136-1248 hours
1248-1400 hours
1400-1520 hours

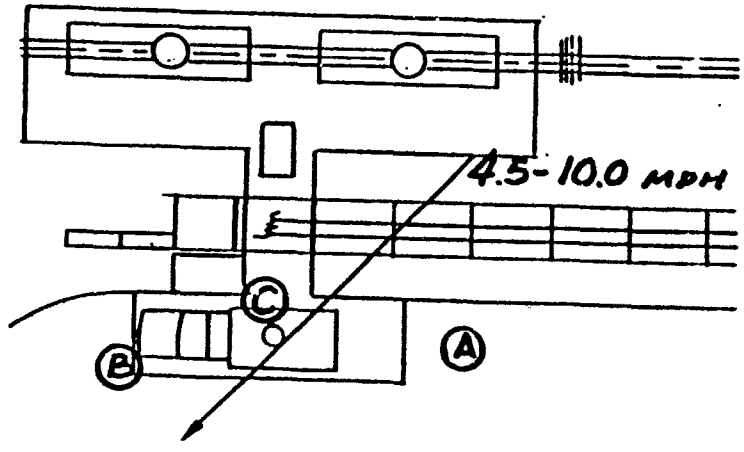


FIGURE 13: 26 June 1980, Sampler locations during all sampling periods.

(A) 35' S of truck connection port.
(B) 60' N of truck conneotion port.
(C) On platform leading to the truck connection port.

Figure 13a Sampling periods: 0815-0915 hours
0915-1015 hours

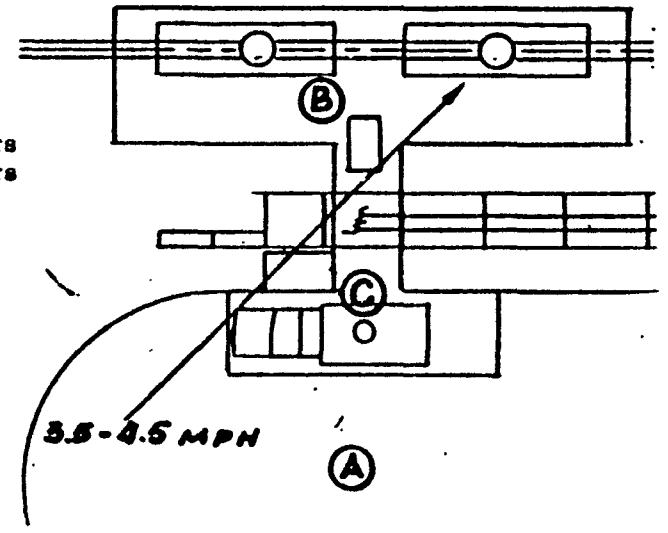
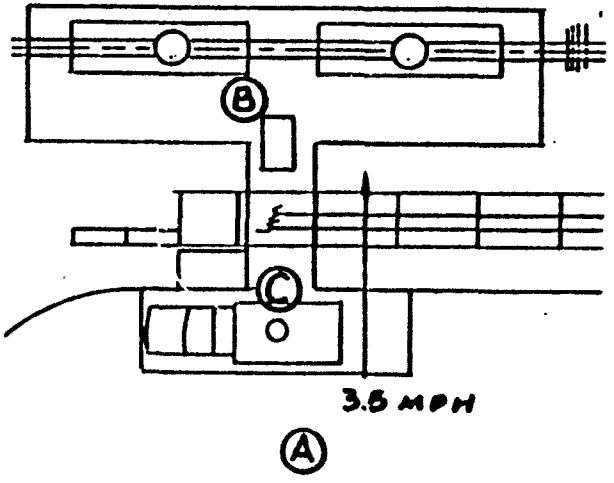


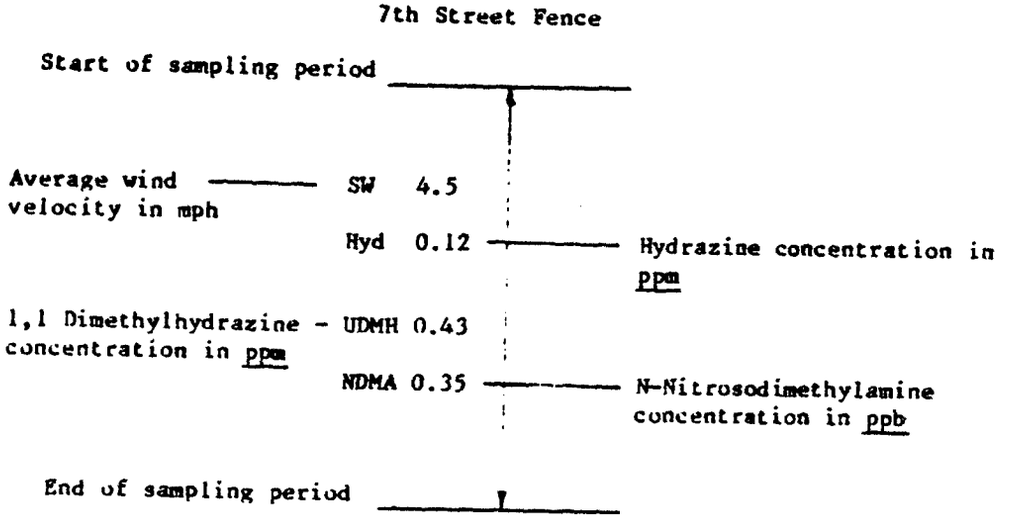
Figure 13b Sampling period: 1015-1120 hours



APPENDIX E

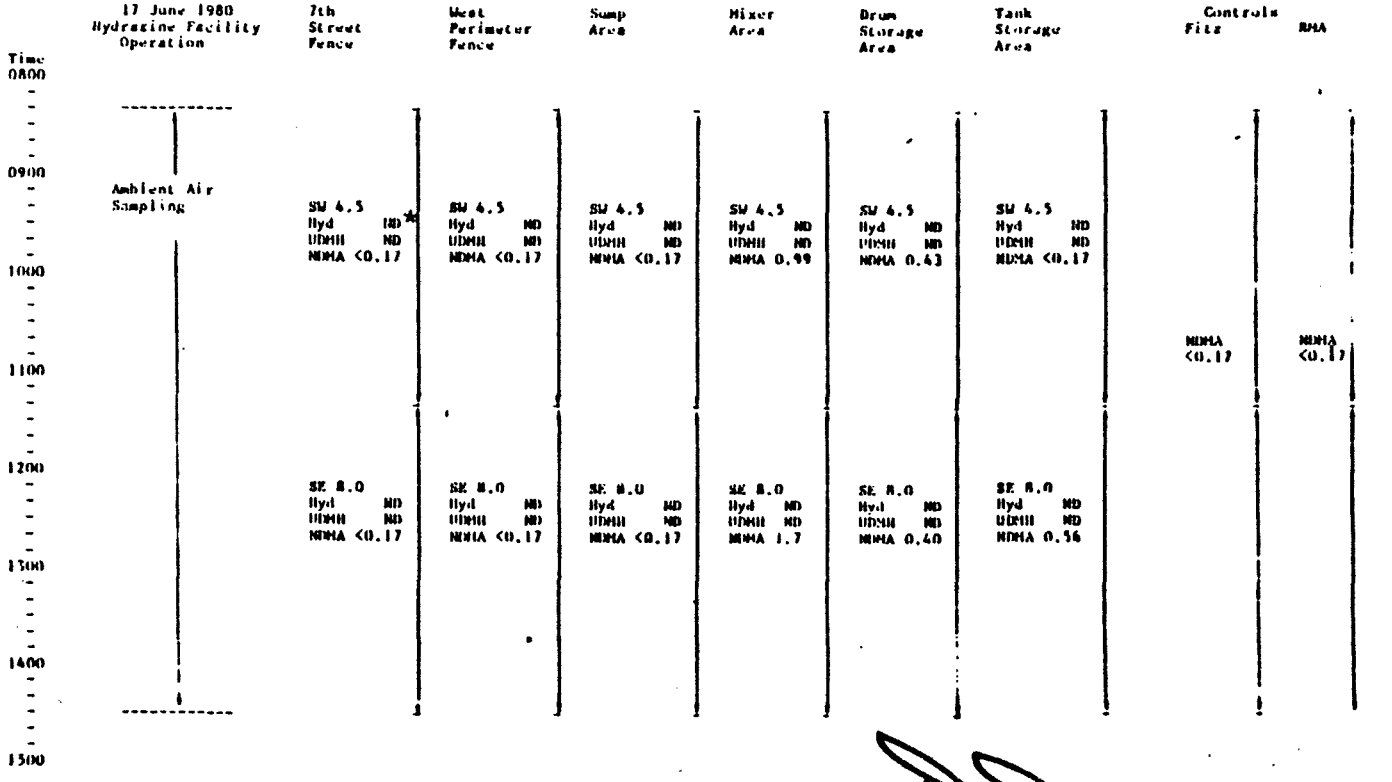
Tabulated Sampling Results
(To be used in conjunction with sampling locations found in Appendix D)

SAMPLE FORMAT



Ind Hyg Special Study No. 55-66-0216-81, N-Nitrosodimethylamine, Hydrazine, and 1, 1-Dimethylamine Exposures at the Hydrazine Blending Facility, RMA, Commerce City, CO, 16-27 Jun 80

APPENDIX E



*ND - <0.01ppm

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APPENDIX E

Time	18 June 1980 Hydrazine Facility Operation	A (upwind)	B (downwind)	C (Source)	7th Street Fence	West Permimeter Fence	Sump Area	Mixer Area	Drum Storage Area	Tank Storage Area	Controls Fitz	Controls RMA
0800												
	Checking System											
0900					M 4.0 Hyd ND UDMH ND NDMA <0.17	M 4.0 Hyd ND UDMH ND NDMA <0.17	M 4.0 Hyd ND UDMH <0.01 NDMA 1.15	M 4.0 Hyd ND UDMH ND NDMA 1.32	M 4.0 Hyd ND UDMH ND NDMA 1.00	M 4.0 Hyd ND UDMH ND NDMA 0.66		
1000	Filling Five Drums with UDMH from Storage Tank USI	NE 4.5 Hyd ND UDMH ND NDMA 3.36 Fig D-2	NE 4.5 Hyd ND UDMH ND NDMA 2.95 Fig D-2	NE 4.5 Hyd 0.06 UDMH 0.11 NDMA 12.5 Fig D-2								
1100											NDMH <0.17	NDMH <0.17
1200												
1300	Rinsing & Steam Cleaning Seven Drums	NE 5.0 Hyd ND UDMH ND NDMA 3.73 Fig D-465	NE 5.0 Hyd ND UDMH ND NDMA 3.32 Fig D-465	NE 5.0 Hyd ND UDMH <.01 NDMA 3.91 Fig D-465	NE 5.0 Hyd ND UDMH ND NDMA 0.98	NE 5.0 Hyd ND UDMH ND NDMA <0.17	NE 5.0 Hyd ND UDMH ND NDMA 0.33	NE 5.0 Hyd ND UDMH ND NDMA 5.05	NE 5.0 Hyd ND UDMH ND NDMA 1.41	NE 5.0 Hyd ND UDMH ND NDMA 0.75		
1400	Filling Six Drums with Hydrazine from ARC 17094	E 4.0 Hyd * UDMH * NDMA 6.61 Fig D-3	E 4.0 Hyd 0.22 UDMH 0.05 NDMA 16.5 Fig D-3	E 4.0 Hyd 0.92 UDMH 0.07 NDMA 22.6 Fig D-3								
1500												

*Sample loss in collection due to breakage

Encl 3

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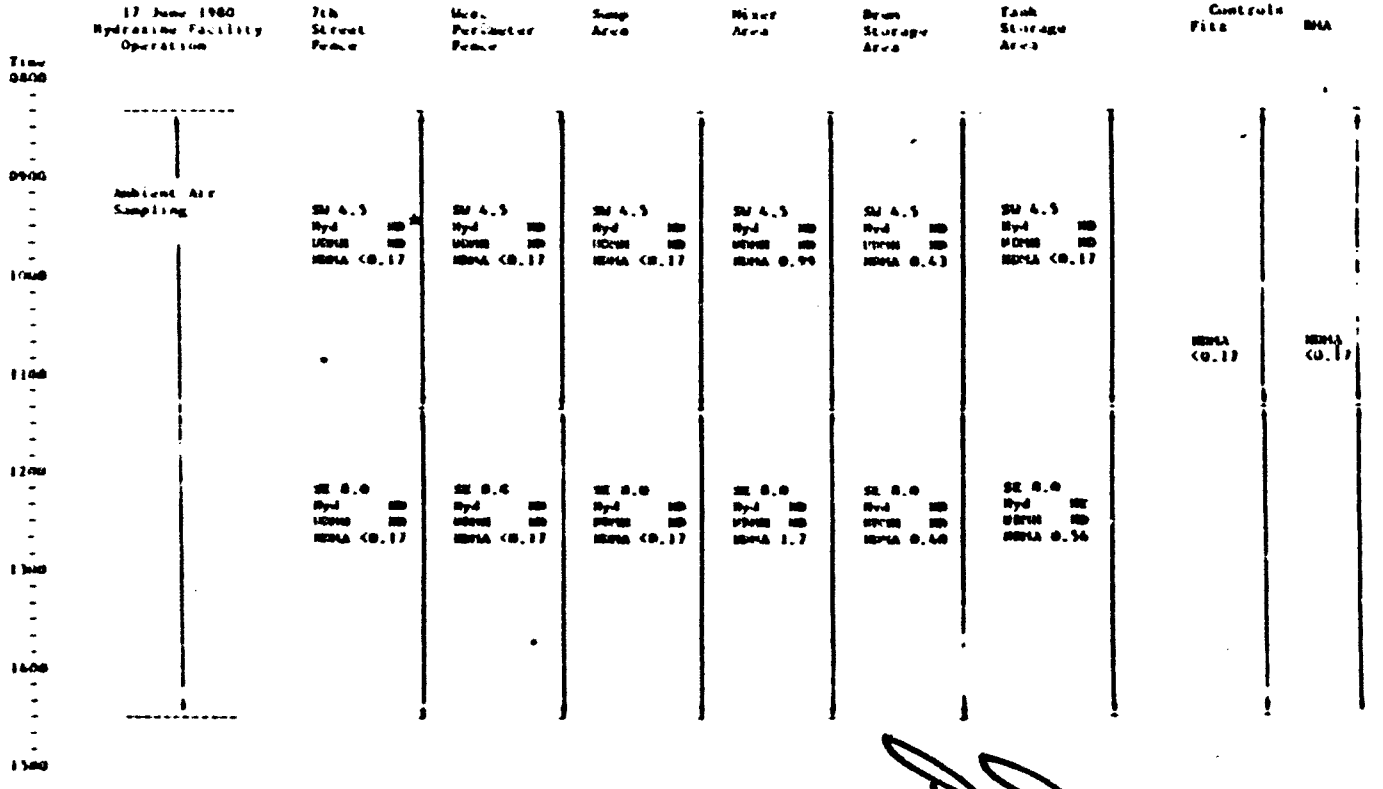
APPENDIX E



*ND - <0.01ppm

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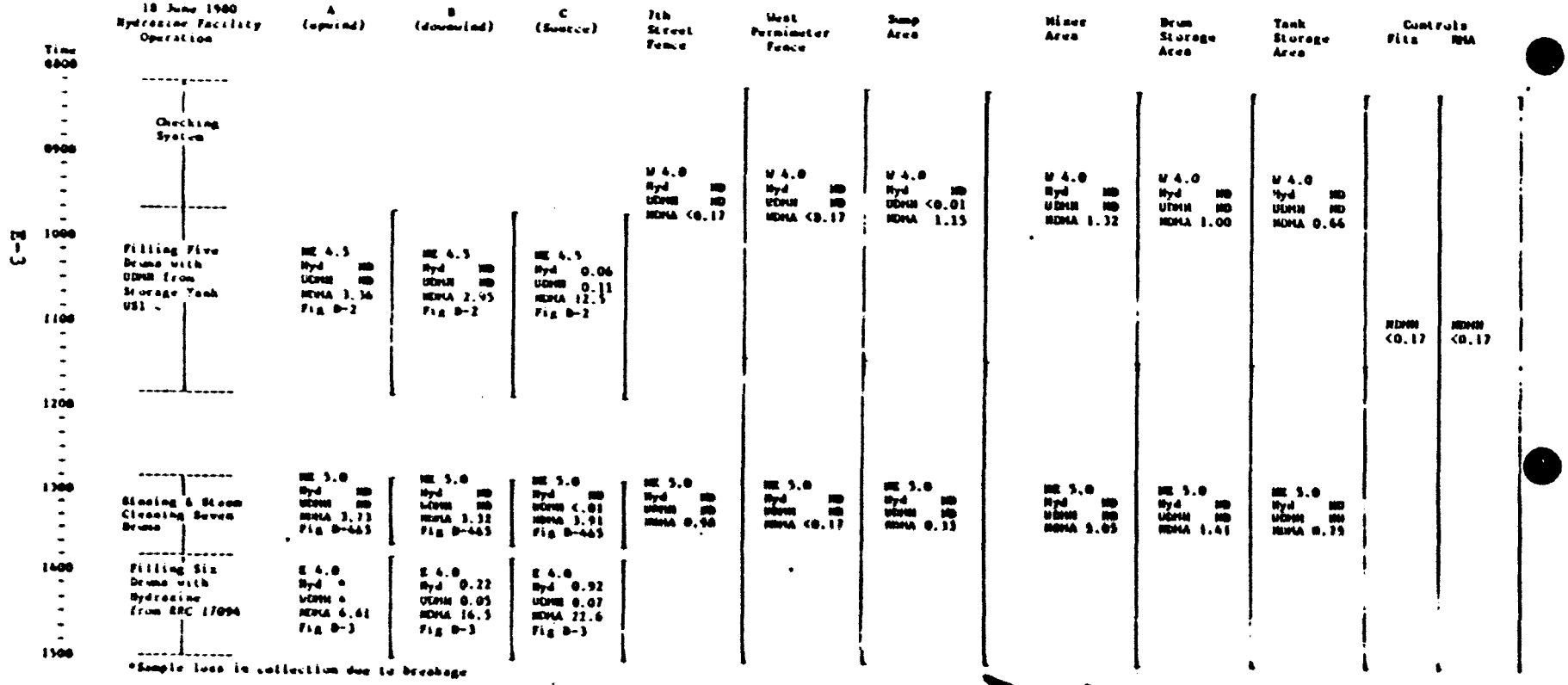
Ind Hyg Special Study No. 55-66-0216-81, N-Nitrosodimethylamine, Hydrazine, and 1, 1-Dimethyldrazine Exposures at the Hydrazine Blending Facility, RMA, Commerce City, CO, 16-27 Jun 80

APPENDIX E



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APPENDIX E

Time	19 June 1980 Hydrazine Facility Operation	A (upwind)	B (downwind)	C (Source)	7th Street Fence	West Perimeter Fence	Sump Area	Mixer Area	Drum Storage Area	Tank Storage Area	Building 759	Controls Fitz	Controls RMA
0800													
	Unhooked REC #17094												
0900	Hooked REC #17068	H 7.0 Hyd ND NDMA <0.17 Fig D-6a	H 7.0 Hyd ND NDMA <0.17 Fig D-6a	H 7.0 Hyd ND NDMA <0.17 Fig D-6a	H 6.5 Hyd ND NDMA <0.17	H 6.5 Hyd ND NDMA <0.17	H 6.5 Hyd ND NDMA <0.17	H 6.5 Hyd ND NDMA <0.17	H 6.5 Hyd ND NDMA 0.72	H 6.5 Hyd <0.01 NDMA <0.17			
1000	Transfered Hydrazine from REC 17068 to Storage Tank No. NA502	H 7.0 Hyd ND NDMA <0.17 Fig D-6a	H 7.0 Hyd ND NDMA <0.17 Fig D-6a	H 7.0 Hyd ND NDMA <0.17 Fig D-6a								<0.17 NDMA	<0.17 NDMA
1100		H 5.0 Hyd ND NDMA <0.17 Fig D-6a	H 5.0 Hyd ND NDMA 1.57 Fig D-6a	H 5.0 Hyd ND NDMA <0.17 Fig D-6a									
1200		EHE 4.5 Hyd ND NDMA 0.20 Fig D-6b	EHE 4.5 Hyd ND NDMA 1.87 Fig D-6b	EHE 4.5 Hyd ND NDMA 0.46 Fig D-6b	HE 5.0 Hyd ND NDMA <0.17	HE 5.0 Hyd ND NDMA <0.17	HE 5.0 Hyd ND NDMA 0.26	HE 5.0 Hyd ND NDMA 0.72	HE 5.0 Hyd ND NDMA 0.58	HE 5.0 Hyd ND NDMA 1.16	NDMA <0.17**		
1300													
	Unhooked REC #17068	HE 5.0 Hyd ND NDMA <0.17 Fig D-6c	HE 5.0 Hyd <0.01 NDMA 0.59 Fig D-6c	HE 5.0 Hyd * NDMA <0.17 Fig D-6c									
1400													
1500													

* Sample loss in analysis
** Sample collected on Tenax®

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Ind Hyg Special Study No. 55-66-0216-81, N-Nitrosodimethylamine, Hydrazine, and 1, 1-Dimethylamine Exposures at the Hydrazine Blending Facility, RMA, Commerce City, CO, 16-27 Jun 80

APPENDIX E

Time	20 June 1980 Hydrazine Facility Operation	A (upwind)	B (downwind)	C (Source)	7th Street Fence	West Perimeter Fence	Sump Area	Mixer Area	Drum Storage Area	Tank Storage Area	Building 759	Controls Pits	Controls RMA
0800													
	Spotted RRC	MW 3.0	MW 3.0	MW 3.0									
	Changed Flanges	UDMH <0.01	UDMH 0.01	UDMH 0.02									
0900	Hooked Truck	NDMA 6.37	NDMA 0.60	NDMA 6.68									
	and Transferred	Fig B-7a	Fig B-7a	Fig B-7a									
	UDMH into Truck												
	From US-2												
					ME 6.5	ME 6.5	ME 6.5	ME 6.5	ME 6.5	ME 6.5			
		MWE 5.5	MWE 5.5	MWE 5.5	Hyd <0.01	Hyd ###	Hyd <0.01	Hyd <0.01	Hyd <0.01	Hyd <0.01		<0.17*	<0.17
1000		UDMH 0.01	UDMH 0.01	UDMH <0.01	UDMH <0.01	UDMH 0.01	UDMH <0.01	UDMH 0.01	UDMH 0.01	UDMH <0.01	ME 6.5	NDMA	NDMA
		NDMA 7.60	NDMA 0.26	NDMA 2.37	NDMA <0.17	NDMA 0.17	NDMA 1.72	NDMA 2.75	NDMA 1.42	NDMA 1.25	NDMA <0.17*		
		Fig B-7b	Fig B-7b	Fig B-7b									
	Transferred H_2												
	Blanket and												
	Unhooked Truck												
1100	Transferred	ME 7.5	ME 7.5	ME 7.5									
	Aerozine 50	Hyd <0.01	Hyd ##	Hyd 0.01									
	From RAS 3	UDMH 0.01	UDMH ##	UDMH 0.01									
	to RRC #17068	NDMA <0.17	NDMA 2.01	NDMA 0.18									
		Fig B-8	Fig B-8	Fig B-8									
1200													
1300													
1400													
1500													

*Sample collected on Tenax®
**Sample loss in analysis
***Sample not analyzed for Hydrazine

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Ind Hyg Special Study No. 55-66-0216-81, N-Nitrosodimethylamine, Hydrazine, and 1, 1-Dimethylamine Exposures at the Hydrazine Blending Facility, RMA, Commerce City, CO, 16-27 Jun 80

APPENDIX E

Time	23 June 1980 Hydrazine Facility Operation	A (upwind)	B (downwind)	C (Source)	7th Street Fence	West Perimeter Fence	Sump Area	Mixer Area	Drum Storage Area	Tank Storage Area	Controls Pits	Controls RMA
0800												
0900	Delay due to charging of sump				S 5.0 Hyd ND UDMH 0.01 NDMA 0.57	S 5.0 Hyd <0.01 UDMH <0.01 NDMA <0.17		S 5.0 Hyd <0.01 UDMH 0.01 NDMA 0.63	S 5.0 Hyd ND UDMH 0.13 NDMA 1.00	S 5.0 Hyd ND UDMH 0.01 NDMA <0.17		
1000												
1100	Transferred Aerozine 50 from RSC 17068 to HAS 1	SW 5.0 Hyd <0.01 UDMH 0.01 NDMA 0.42 Fig D-9	SW 5.0 Hyd ND UDMH 0.02 NDMA 1.83 Fig D-9	SW 5.0 Hyd <0.01 UDMH 0.02 NDMA 2.26 Fig D-9			SE 5.0 Hyd <0.01 UDMH 0.01 NDMA 2.28				<0.17 NDMA	<0.17 NDMA
1200												
1300	Sampled tanks US 1 & US 2 Delay awaiting sample results also changed filter in mixer	ESE 7.5 Hyd ND UDMH 0.02 NDMA <0.17 Fig D-10	ESE 7.5 Hyd ND UDMH 0.02 NDMA 3.12 Fig D-10	ESE 7.5 Hyd ND UDMH 0.02 NDMA 2.67 Fig D-10	SE 6.5 Hyd <0.01 UDMH 0.01 NDMA <0.17	SE 6.5 Hyd ND UDMH 0.02 NDMA 0.18	E 7 Hyd <0.01 UDMH 0.01 NDMA 2.89	SE 6.5 Hyd ND UDMH 0.01 NDMA 5.55	SE 6.5 Hyd <0.01 UDMH 0.01 NDMA 1.48	SE 6.5 Hyd ND UDMH 0.01 NDMA 0.75		
1400												
1500	Booked truck #2793	E 7.0 Fig D-11	E 7.0 Fig D-11	E 7.0 Fig D-11								

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APPENDIX E

Time	24 June 1980 Hydrazine Facility Operation	A (upwind)	B (downwind)	C (Source)	7th Street Fence	West Perimeter Fence	Sump Area	Mixer Area	Drum Storage Area	Tank Storage Area	Bldg 759	Controls - Pitz	Controls - RMA
0800													
	Delay awaiting sample results												
0900													
	Purged truck 2793 with UDMH	NE 5.5 Hyd ND UDMH 0.03 NDMA <0.17	NE 5.5 Hyd 0.03 UDMH 0.06 NDMA 19.5	NE 5.5 Hyd ND UDMH 0.01 NDMA 0.81	NE 5.0 Hyd ND UDMH <0.01 NDMA <0.17	NE 5.0 Hyd ND UDMH 0.01 NDMA 1.23	NE 5.0 Hyd ND UDMH 0.01 NDMA 0.71	NE 5.0 Hyd ND UDMH 0.02 NDMA 1.88	NE 5.0 Hyd ND UDMH 0.01 NDMA 0.34	NE 5.0 Hyd ND UDMH <0.01 NDMA 1.85			
1000	Transferred UDMH from MAS 3 through 10 micron filter into truck 2793	Fig D-12	Fig D-12	Fig D-12							NE 9 Hyd UDMH <0.01 NDMA 0.70*		
1100		NE 4.5 UDMH <0.01 NDMA 0.46 Fig D-12	NE 4.5 UDMH 0.02 NDMA 15.3 Fig D-12	NE 4.5 UDMH 0.01 NDMA 1.81 Fig D-12								<0.17 NDMA	<0.17 NDMA
1200		NE 6.0 UDMH 0.02 NDMA 1.30 Fig D-12	NE 6.0 UDMH 0.04 NDMA 16.4 Fig D-12	NE 6.0 UDMH 0.02 NDMA 4.01 Fig D-12									
1300		NE 6.5 UDMH 0.02 NDMA 0.94 Fig D-12	NE 6.5 UDMH 0.02 NDMA 16.2 Fig D-12	NE 6.5 UDMH 0.02 NDMA 1.30 Fig D-12	NE 6.5 UDMH 0.01 NDMA <0.17	NE 6.5 UDMH <0.01 NDMA 2.35	NE 6.5 UDMH <0.01 NDMA 1.21	NE 6.5 UDMH 0.02 NDMA 2.14	NE 6.5 UDMH 0.02 NDMA 0.50	NE 6.5 UDMH 0.02 NDMA 2.33	NE 11 UDMH 0.02 NDMA <0.17*		
1400													
1500	Removed and inspected filter	NE 10 UDMH 0.01 NDMA 0.39 Fig D-12	NE 10 UDMH 0.03 NDMA 18.9 Fig D-12	NE 10 UDMH <0.01 NDMA 1.56 Fig D-12									

*Sample collected on Tenax®

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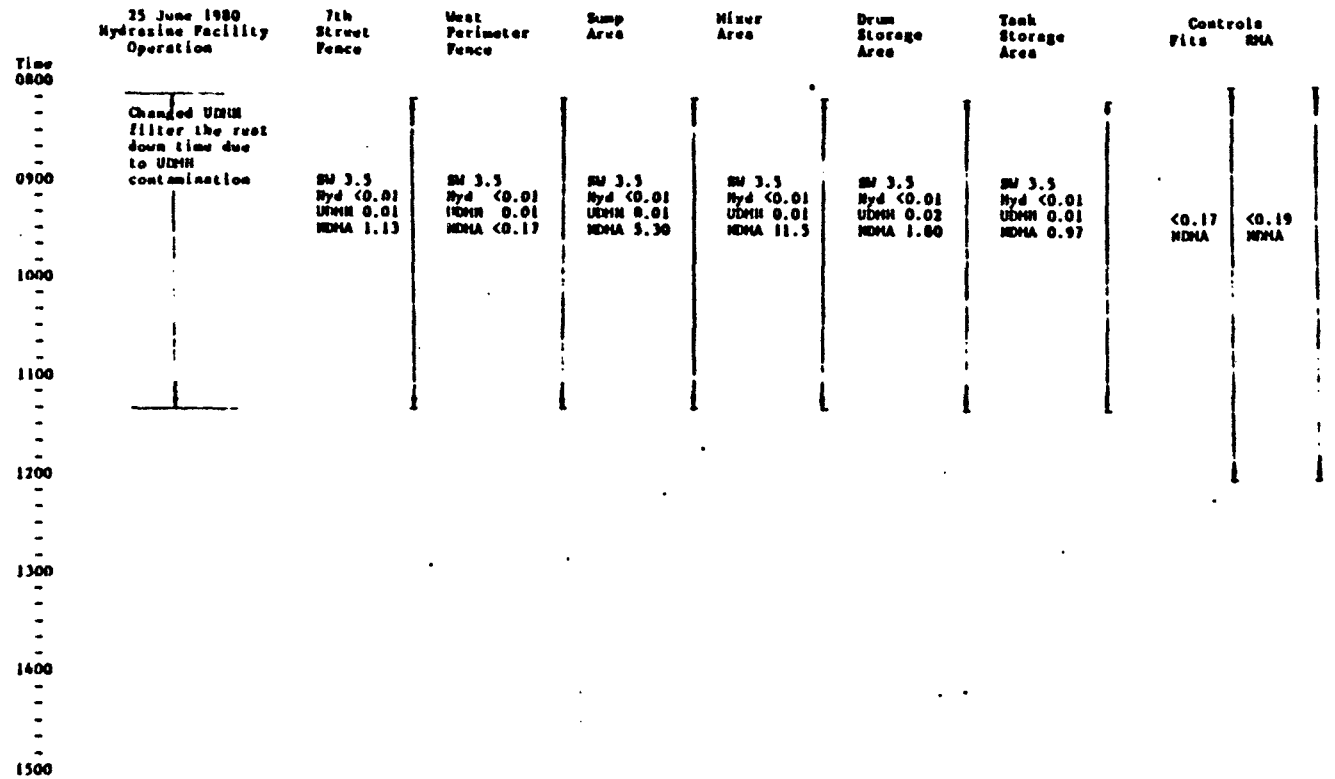
APPENDIX E



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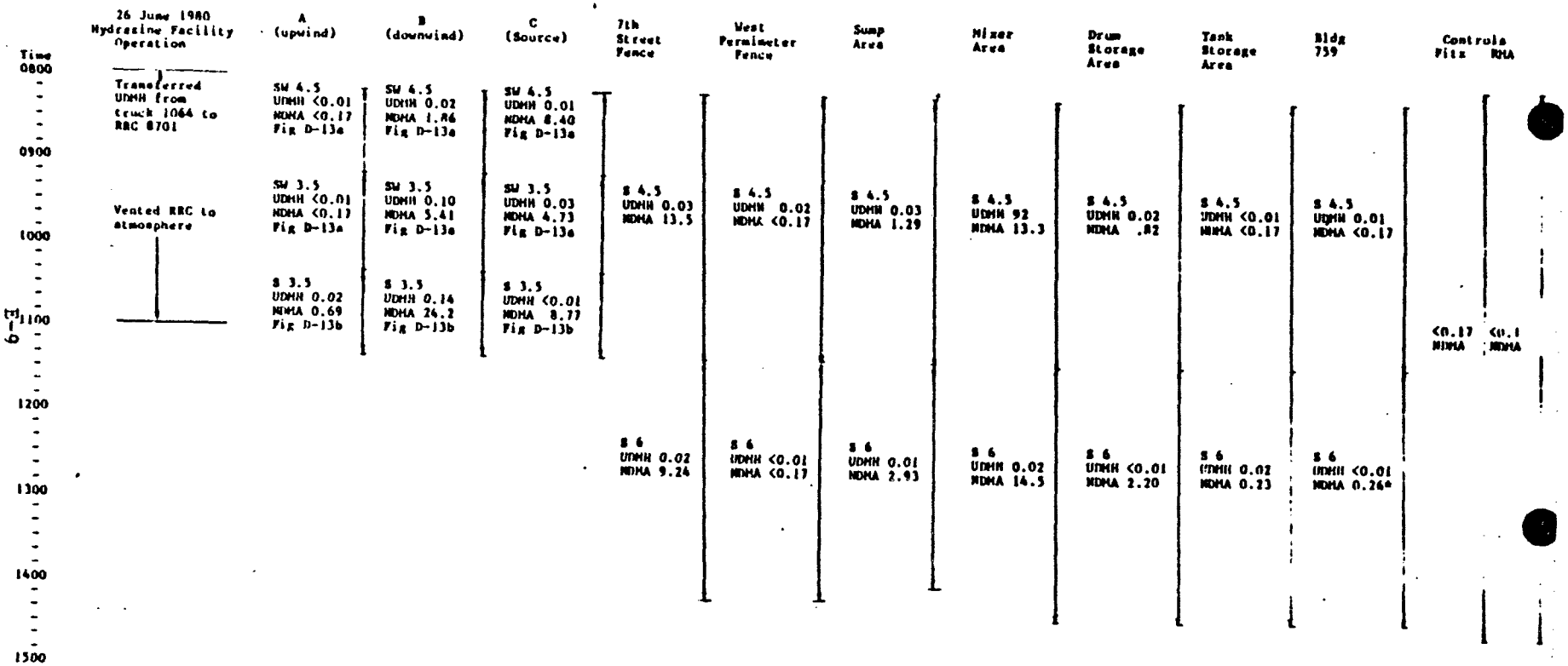
APPENDIX E



*Sample collected on Tenax®

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APPENDIX F
Tabulated List of NDMA Sampling Results
Thermosorb® vs Tenax®
Columns of results correlates to those found in Appendix E left to right, top to bottom
Values given in ppb

17th		18th		19th		20th		23rd		24th		25th		26th	
Therm	Tenax	Therm	Tenax	Therm	Tenax	Therm	Tenax	Therm	Tenax	Therm	Tenax	Therm	Tenax	Therm	Tenax
<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	0.57	<0.17	<0.17	<0.17	1.13	<0.17	<0.17	<0.17
<0.17	<0.17	<0.17	0.45	<0.17	<0.17	0.17	<0.17	<0.17	<0.17	1.23	0.24	<0.17	<0.17	1.86	0.83
<0.17	<0.17	1.15	<0.17	<0.17	<0.17	1.72	<0.17	2.28	0.26	0.71	*	5.30	*	8.40	1.87
0.99	0.17	1.32	3.64	<0.17	<0.17	2.75	0.37	0.63	1.09	1.88	0.89	11.5	0.34	13.5	0.83
0.43	<0.17	1.00	0.31	0.72	0.30	1.42	<0.17	1.00	0.18	0.34	0.17	1.80	0.17	<0.17	0.17
<0.17	<0.17	0.66	0.21	<0.17	<0.17	1.25	0.17	<0.17	<0.17	1.85	<0.17	0.97	<0.17	1.29	*
<0.17	*	<0.17	*	<0.17	*	*	0.17	<0.17	*	<0.17	*	<0.17	*	13.3	1.27
<0.17	*	<0.17	*	<0.17	*	<0.17	*	<0.17	*	<0.17	*	<0.19	*	0.82	<0.17
<0.17	<0.17	3.36	0.78	<0.17	<0.17	<0.17	*	0.42	<0.17	<0.17	<0.17			<0.17	<0.17
<0.17	<0.17	2.95	0.55	<0.17	<0.17	6.37	1.86	1.83	<0.17	19.5	2.15			*	<0.17
<0.17	<0.17	12.5	1.00	<0.17	<0.17	0.60	<0.17	2.26	0.22	0.81	0.17			<0.17	*
1.70	0.26	0.98	<0.17	<0.17	<0.17	6.68	1.53	<0.17	<0.17	*	0.70			<0.17	*
0.40	<0.17	<0.17	<0.17	<0.17	<0.17	7.60	0.48	0.18	<0.17	0.46	<0.17			<0.17	<0.17
0.56	<0.17	0.33	<0.17	<0.17	<0.17	0.26	<0.17	5.55	<0.17	15.3	1.18			5.41	1.98
		5.05	0.99	<0.17	<0.17	2.37	0.31	1.48	<0.17	1.81	0.92			4.73	0.43
		1.41	<0.17	1.57	0.28	<0.17	<0.17	0.75	<0.19	1.30	<0.17			0.69	<0.17
		0.75	<0.17	<0.17	<0.17	2.01	0.75	<0.17	<0.17	16.4	1.00			24.2	1.36
		3.73	<0.17	<0.17	<0.17	0.18	<0.17	3.12	<0.17	4.01	0.33			8.77	0.84
		3.32	<0.17	<0.17	<0.17			2.67	4.96	<0.17	<0.17			9.24	0.33
		3.97	<0.17	0.26	<0.17			2.89	<0.17	2.35	0.44			<0.17	<0.17
		6.61	0.54	0.72	0.22					1.21	*			2.93	*
		16.5	0.88	0.38	0.62					2.14	0.24			14.5	0.37
		22.6	1.05	1.11	*					0.50	<0.17			2.20	<0.17
				*	<0.17					2.33	<0.17			0.23	<0.17
				0.20	<0.17					*	<0.17			*	0.26
				1.87	0.55					0.94	0.50				
				0.46	<0.17					16.2	0.40				
				<0.17	<0.17					1.30	0.34				
				0.59	0.25					0.39	<0.17				
				<0.17	<0.17					18.9	0.85				
										1.54	0.30				

*Comparative samples not run